

# Human visual system

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Dr. Tushar Sandhan

# Introduction

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- Mantis shrimp



- Tarsier



# Introduction

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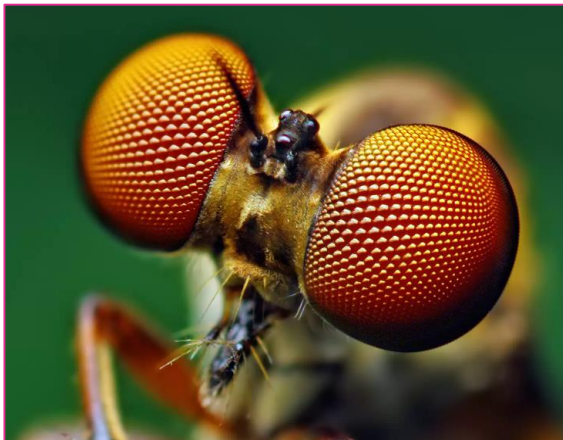
- Mantis shrimp



- Tarsier



- Robber fly



# Introduction

- Mantis shrimp



- Tarsier

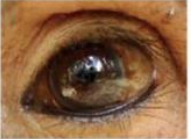


- Great ape species

Chimpanzee  
(*Pan troglodytes*)



Bornean orangutan  
(*Pongo pygmaeus*)



Mountain gorilla  
(*Gorilla beringei*)



Sumatran orangutan  
(*Pongo abelii*)



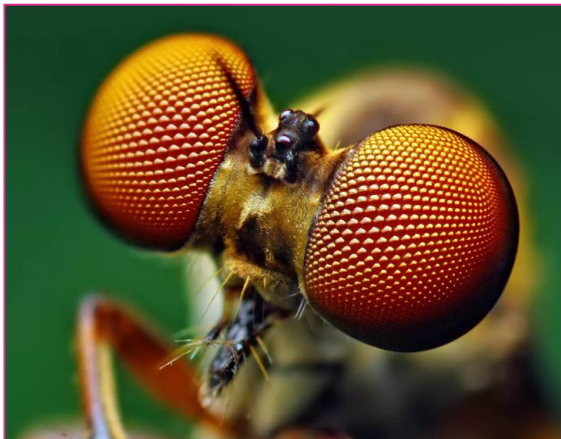
Lowland gorilla  
(*Gorilla gorilla*)



Human  
(*Homo sapiens*)



- Robber fly



$$\text{Sclera Area Index} = \text{Sclera area} / \text{Eye-opening area}$$

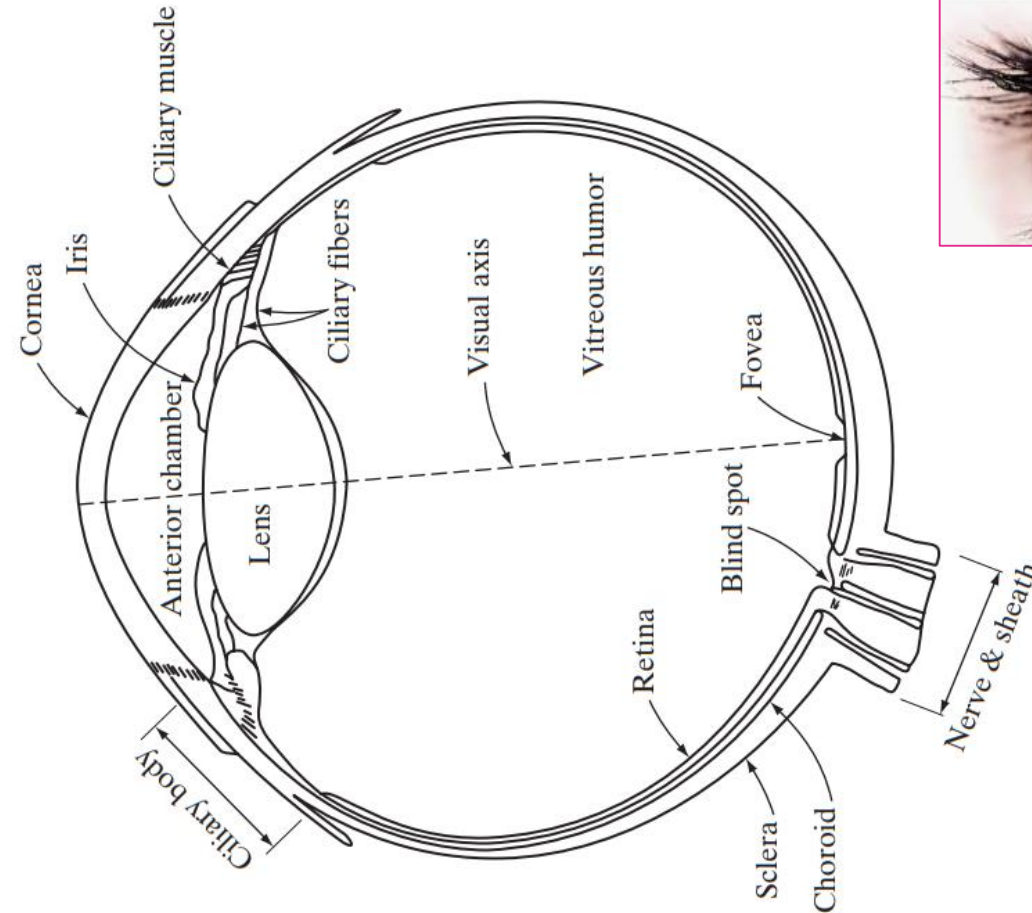
credit: F. Kano et al.



# Human visual system

## ■ EYE

- Cornea
- Sclera
- Choroid (blood vessel network)
  - ciliary body
  - iris (light controller)
    - central opening – pupil
- Lens (concentric fibrous cells)
  - higher proteins – absorb UV, IR
  - cataract
  - F.L. = 14~17mm
- Retina
  - cones (photopic vision - bright light)
  - rods (scotopic vision - dim light)



# Human visual system

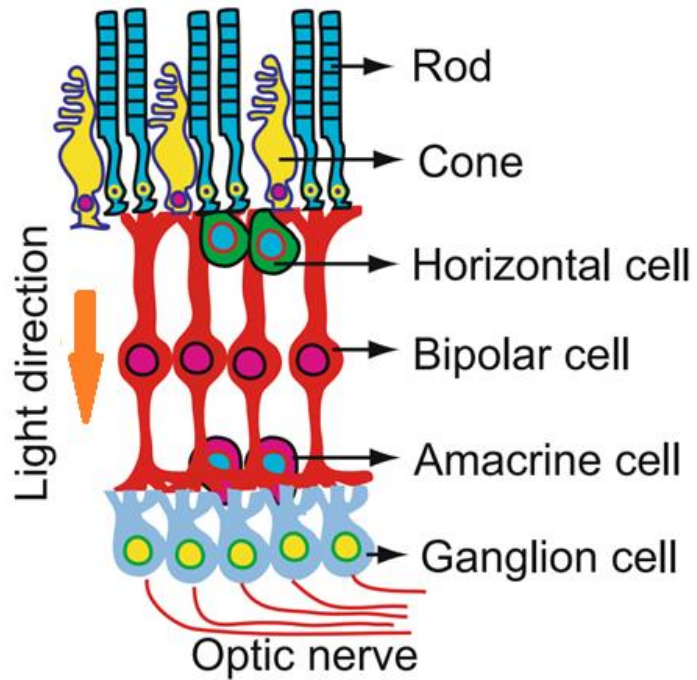
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- Distribution of Rods & Cones
  - blind spot

# Human visual system

- Distribution of Rods & Cones

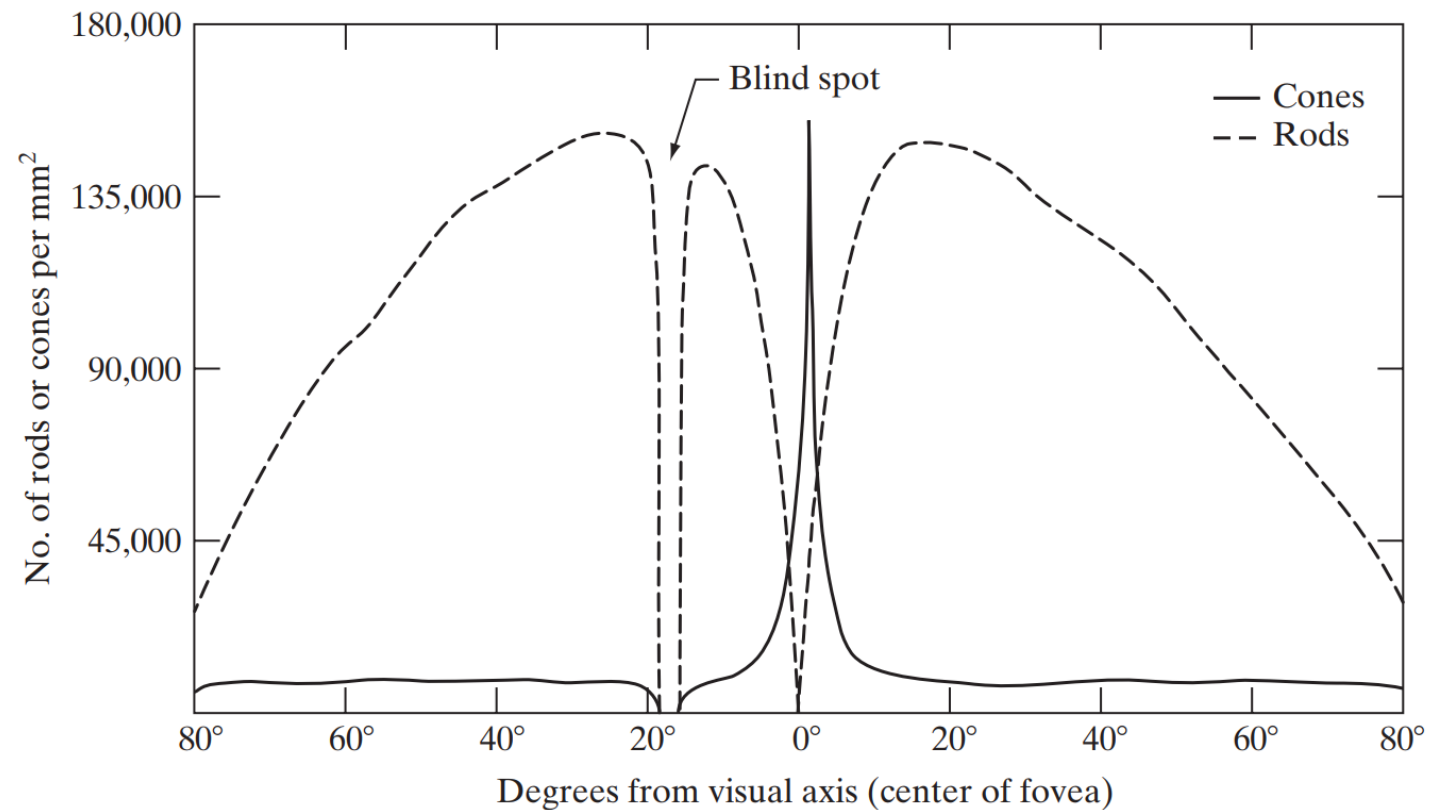
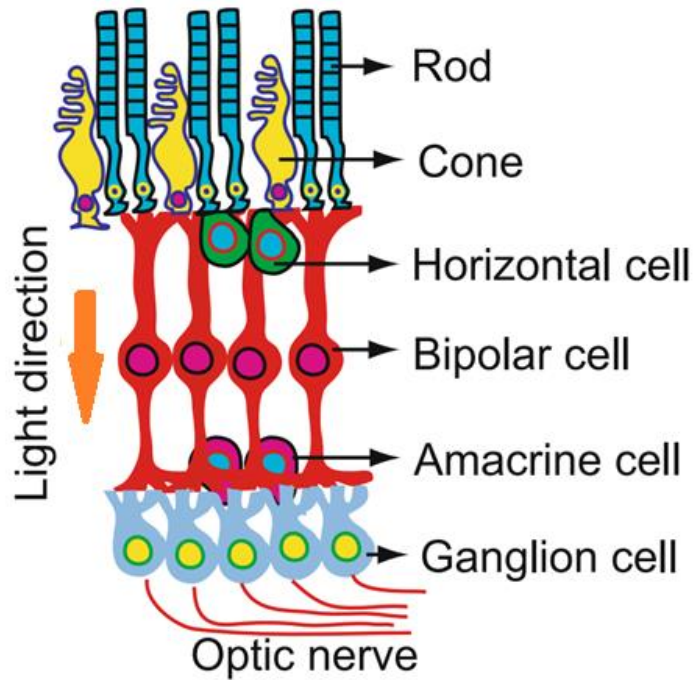
- blind spot



# Human visual system

## ■ Distribution of Rods & Cones

○ blind spot

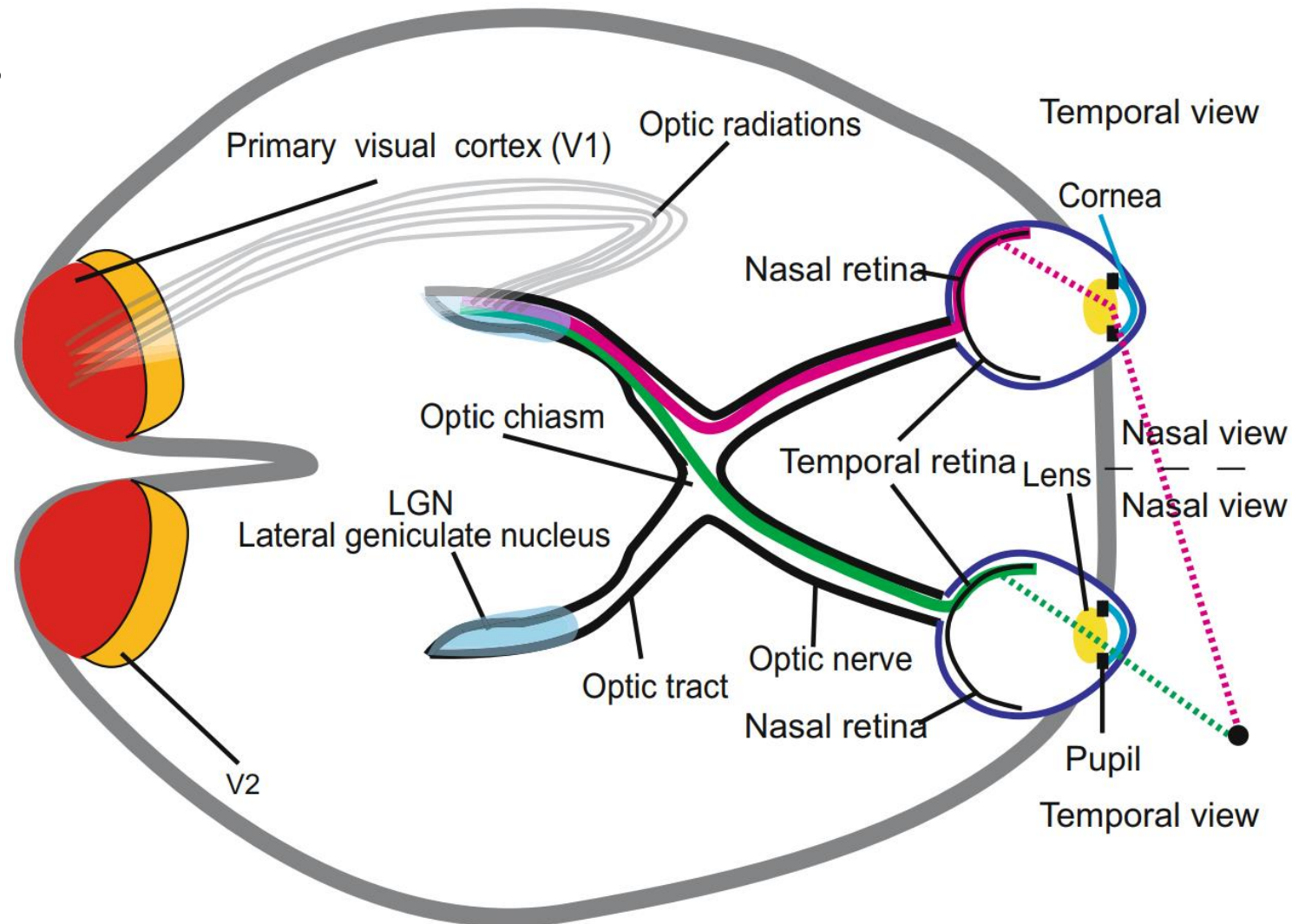




# Human visual systems

- Anatomic pathways

- visual signals



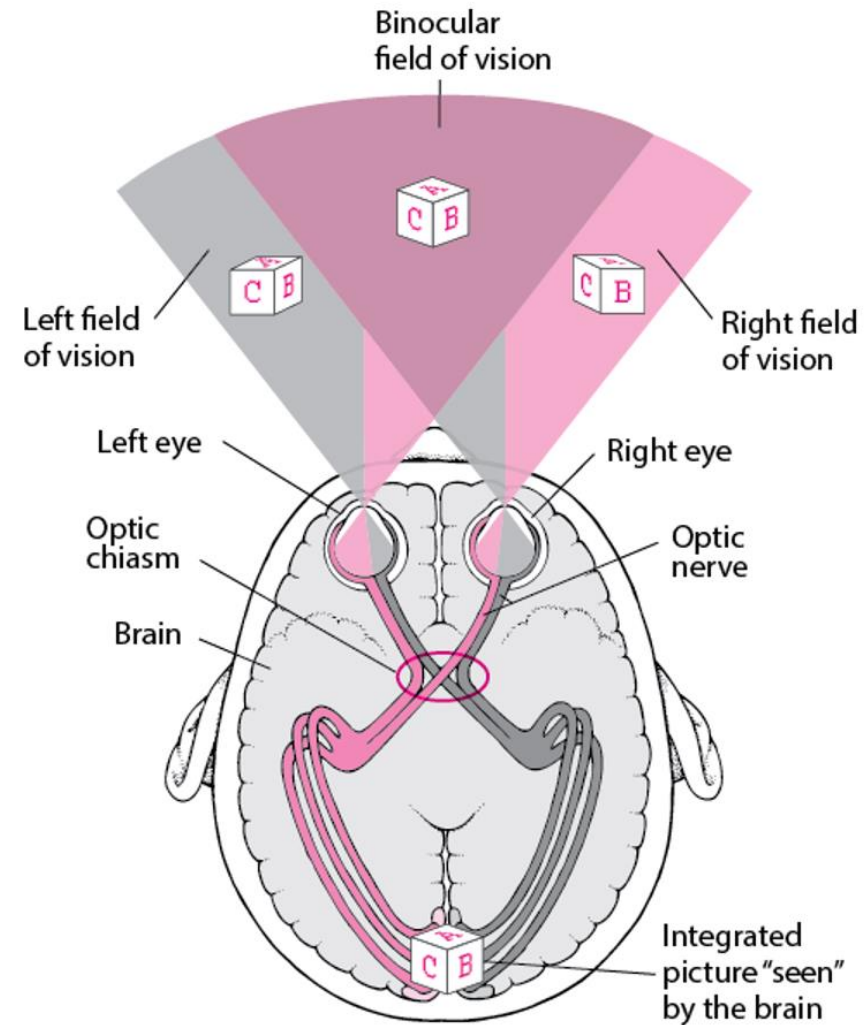
# Human visual system

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- Why two eyes?

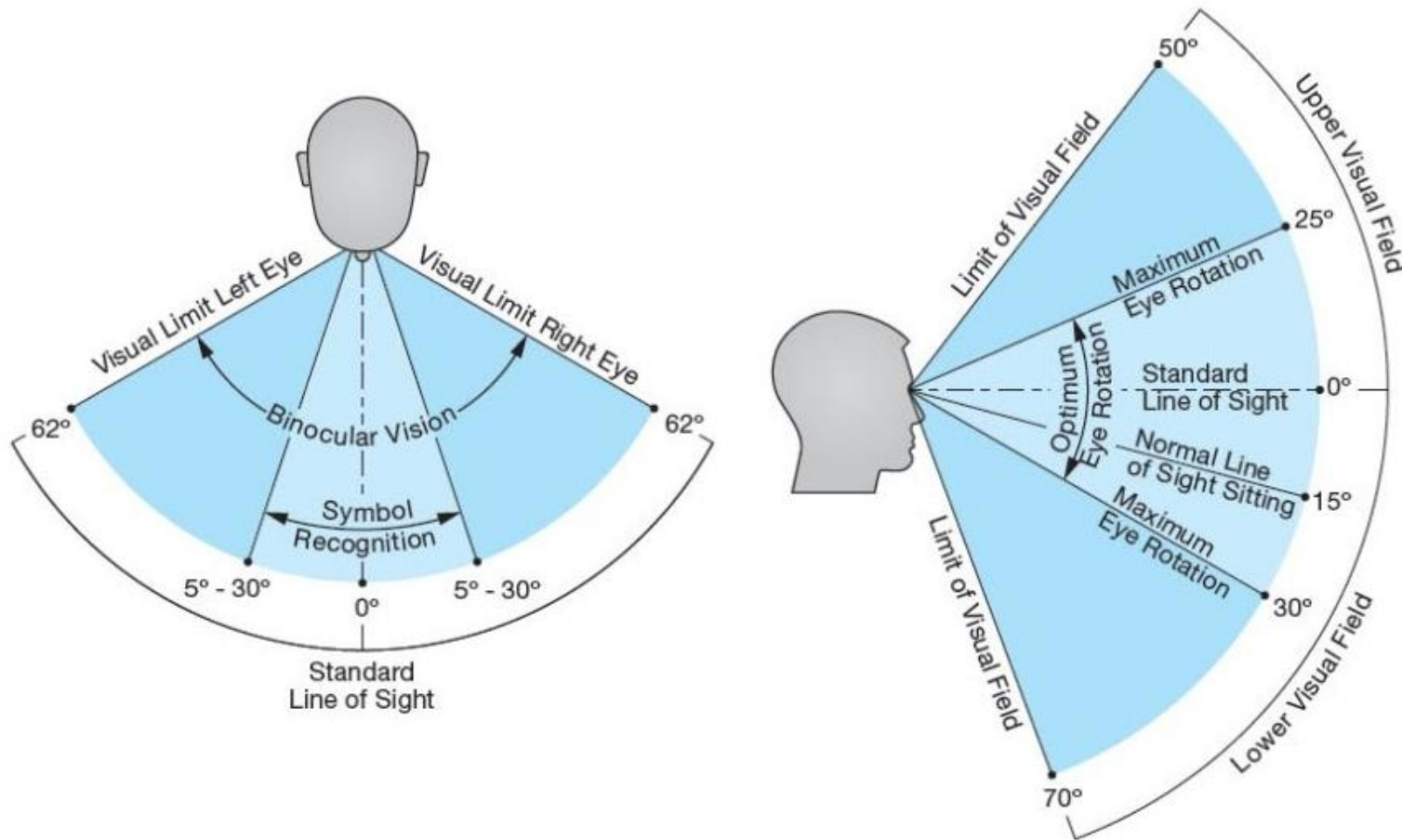
# Human visual system

- Why two eyes?



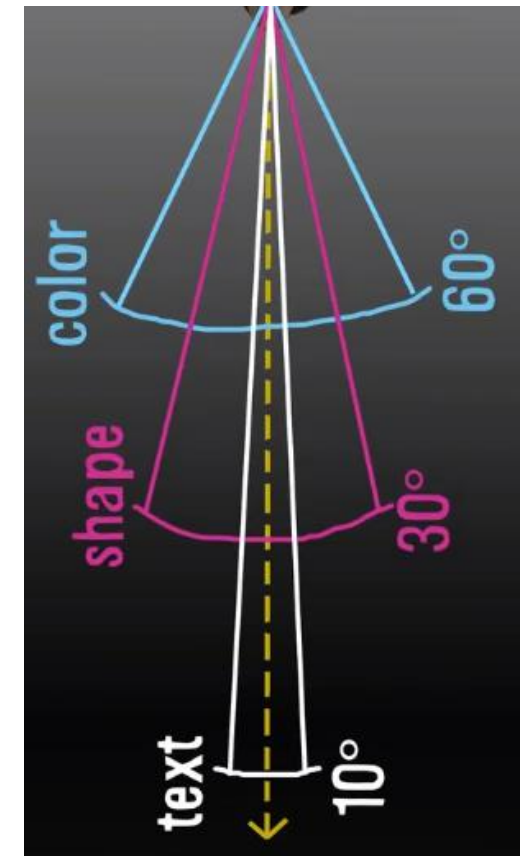
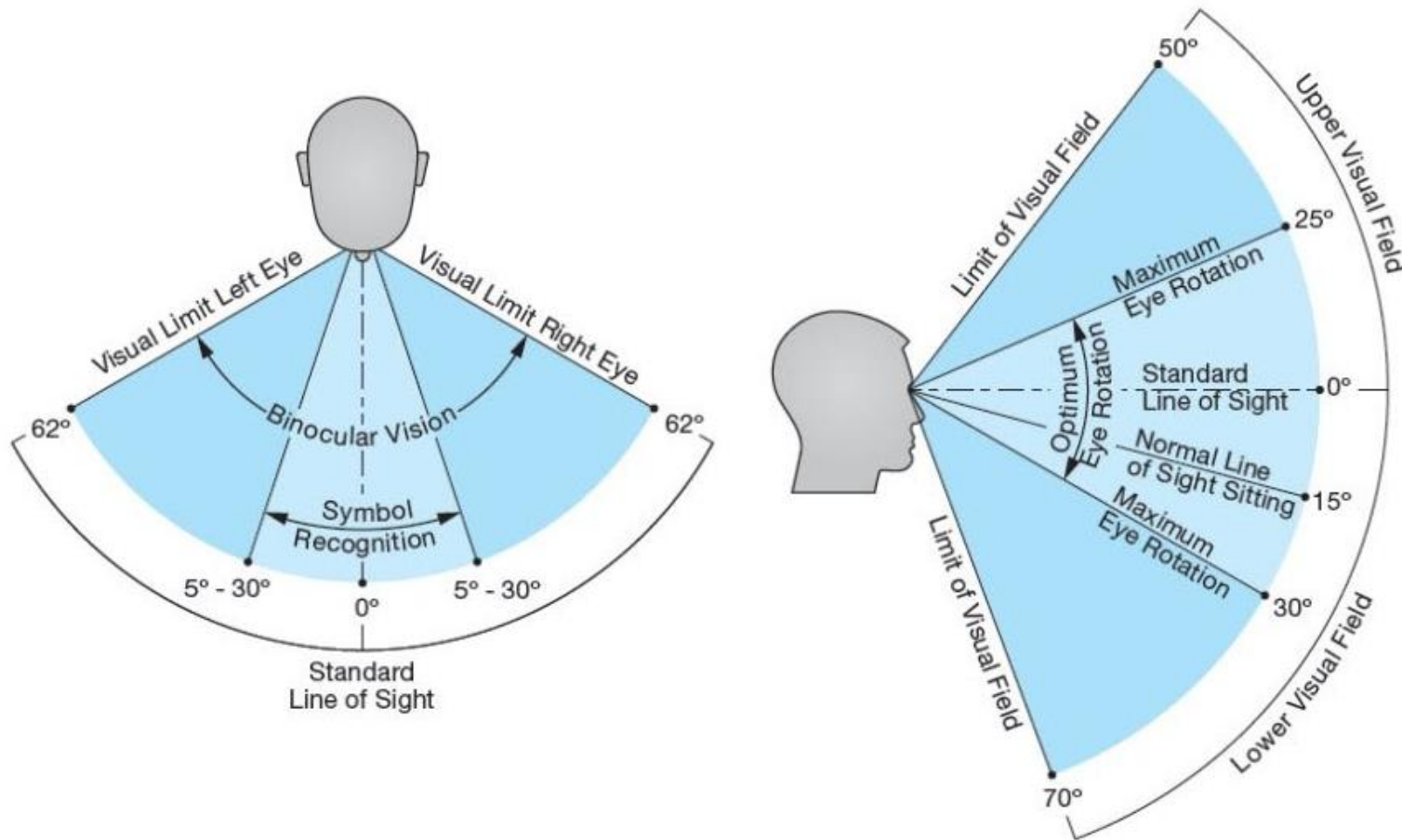
# Human visual system

- Range



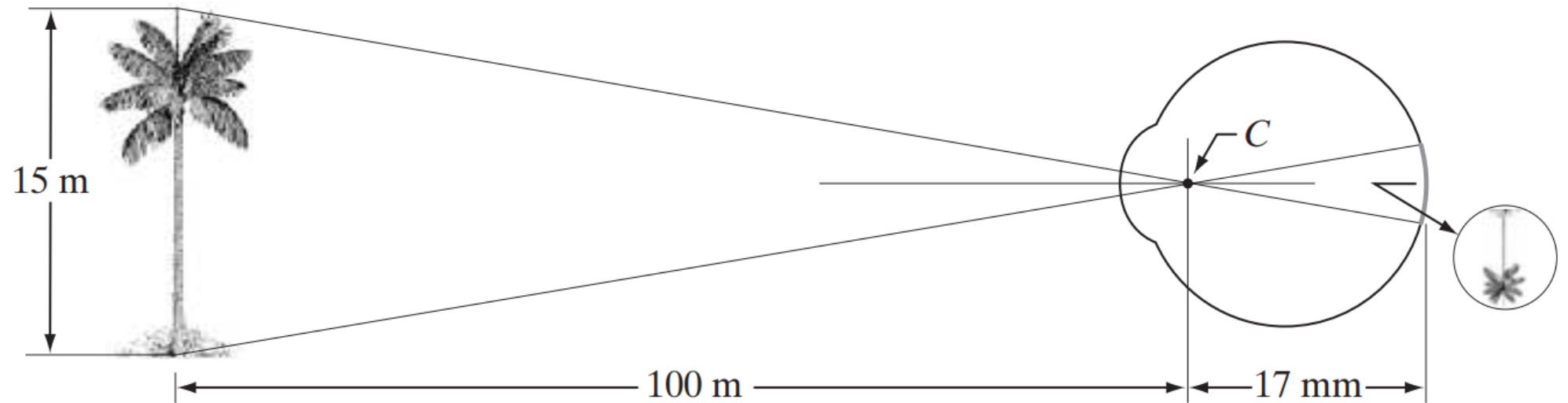
# Human visual system

- Range



# Human visual system

- Image formation
  - inverted over retina



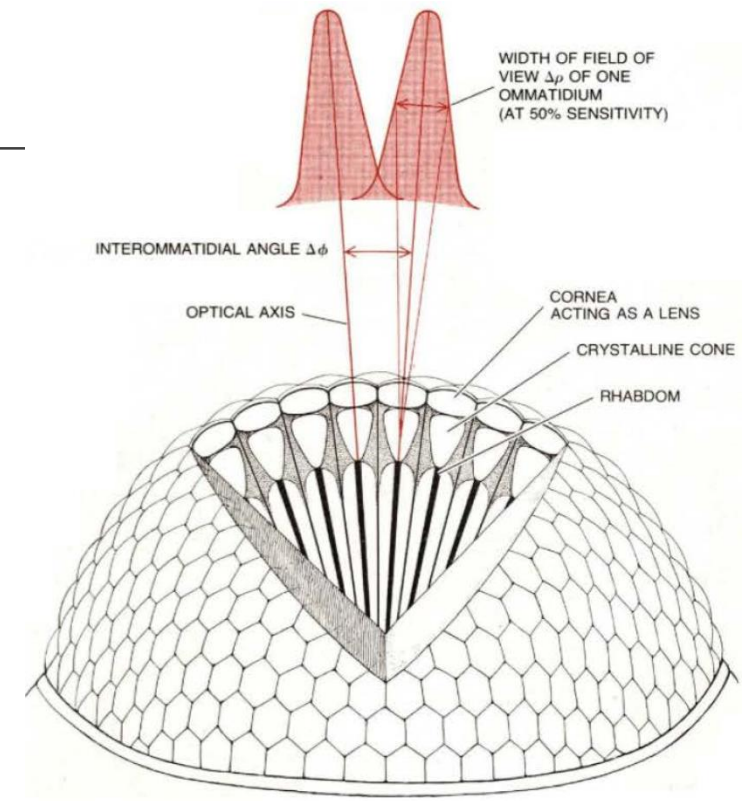
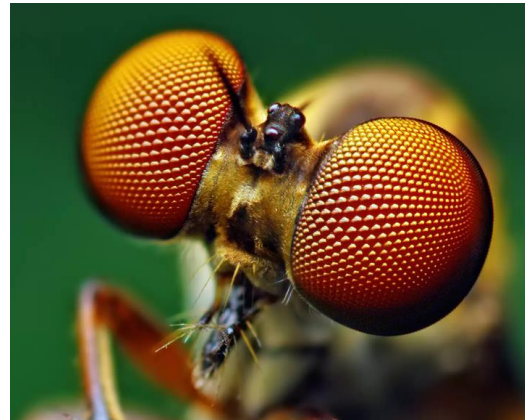


# Fly's vision

## ■ Compound eyes

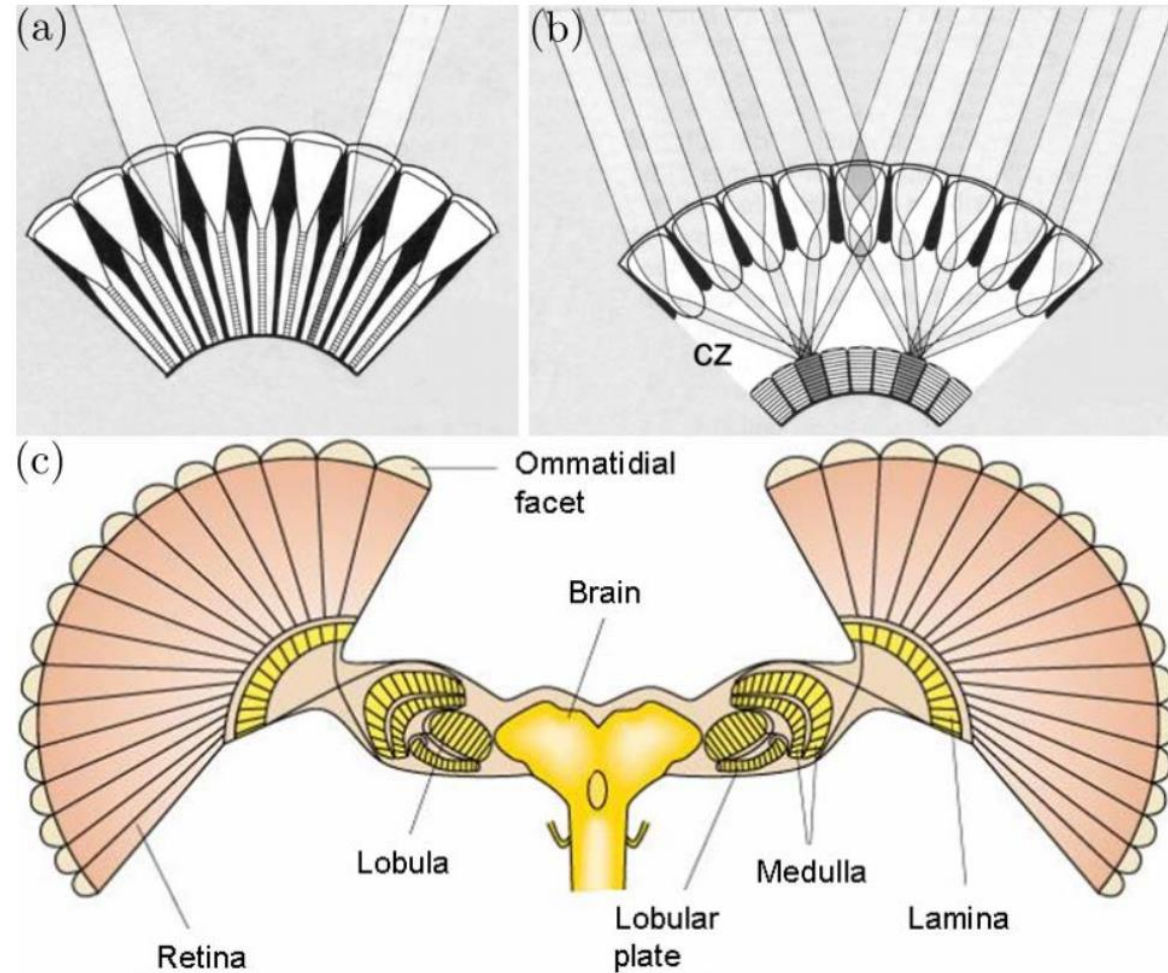
- different from HVS
- hexagonal lens
- 1 ommatidium  $\rightarrow$  8 photoreceptors
- R7, R8 (inner)  $\rightarrow$  color
  - 4 spectral filters: Red to Yellow
- R1~R6 (outer)  $\rightarrow$  motion
- $\Delta\phi$  varies along eye
  - small – frontal regions – flowers, prey detection
  - lens diffraction – Gaussian angular sensitivity
  - spatial LPF – necessary for motion detection
  - $\Delta\phi \approx \Delta\rho$  ensuring no aliasing without oversampling the visual data

Robber fly



# Fly's vision

- Compound eyes
  - Focal apposition
    - day
  - Refracting superposition
    - night
  - Compactness
    - Visual processing immediate beneath ommatidia
    - HVS: wide gap between lens and retina



# General visual systems

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- Light adaption
  - night, cloudy ( $\sim 10^{-2}$  Lux)
  - sunshine ( $\sim 10^5$  Lux)
  - VS need to auto-adapt for maintaining good contrast sensitivity
    - Temporal contrast changes
    - Spatial contrast fluctuations

# General visual systems

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- Light adaption

- night, cloudy ( $\sim 10^{-2}$  Lux)
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  - Spatial contrast fluctuations

- Michaelis-Menten eq

$$V = V_m \frac{I^n}{I^n + \sigma^n},$$

$V$  – photoreceptor's response

$V_m$  – max value

$I$  – light intensity

$n$  – order (0.7~1.0)

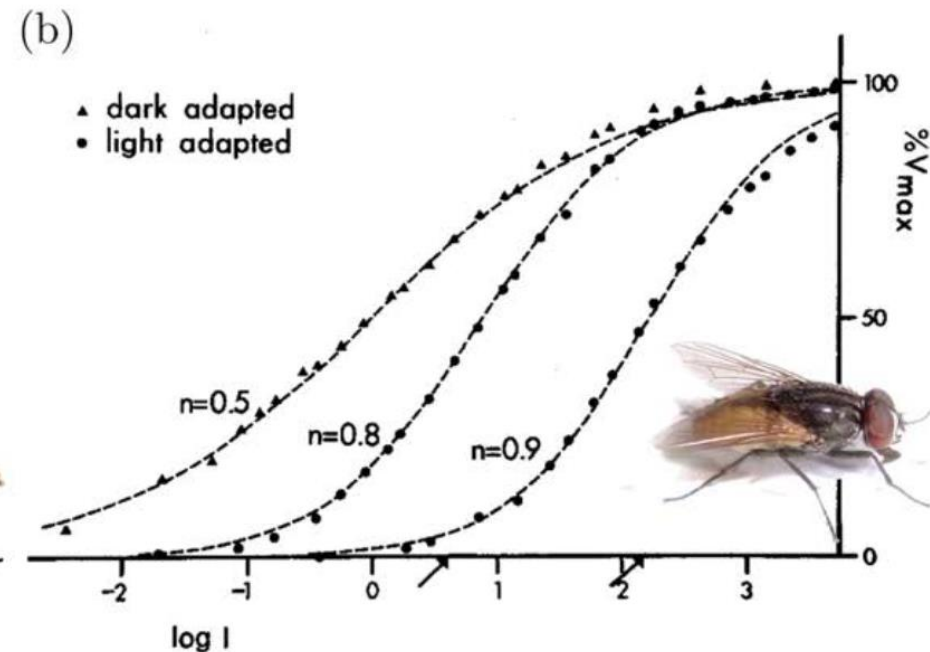
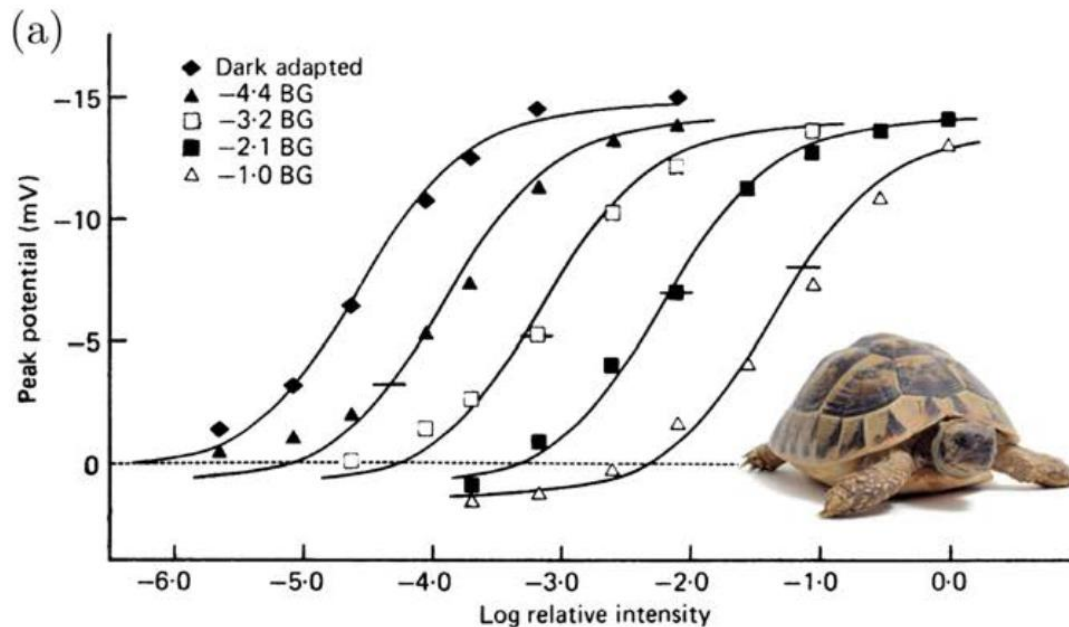
$\sigma$  – adaptation parameter

# General visual systems

## ■ Light adaption

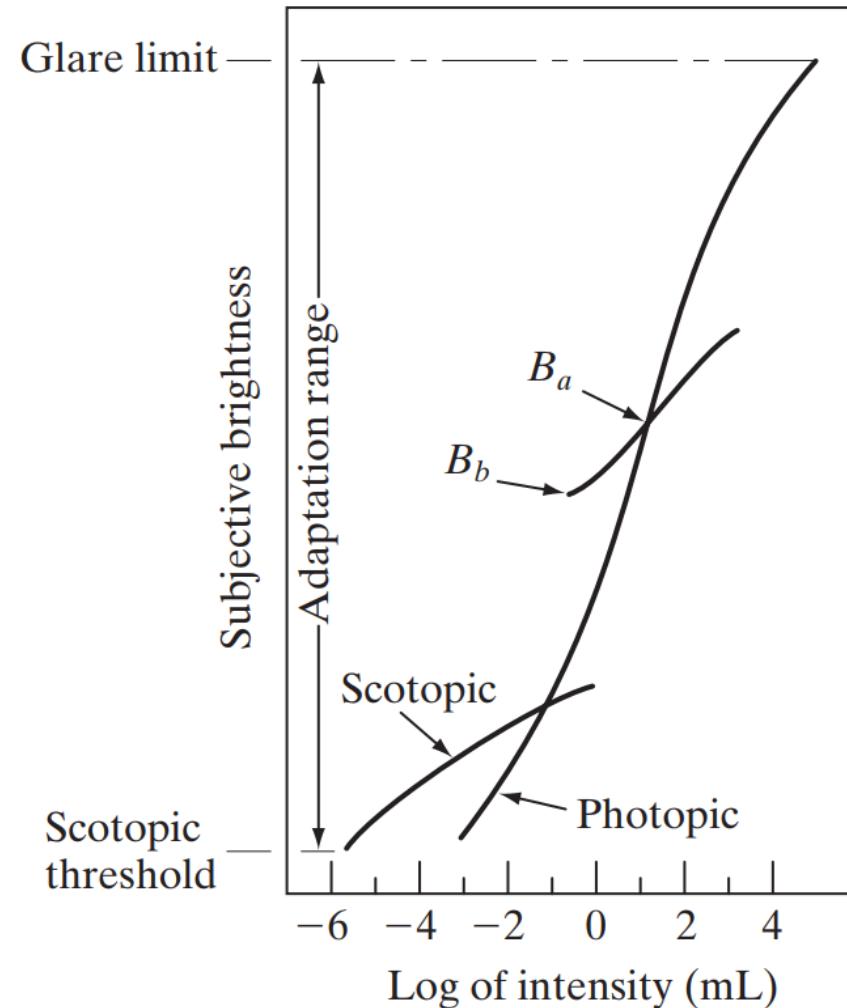
- BG lighting change cause entire 'S' curve to shift along light intensity
- i.e. change in sensitivity of photoreceptor
- slope at operating point: contrast sensitivity

$$V = V_m \frac{I^n}{I^n + \sigma^n},$$



# Human visual system

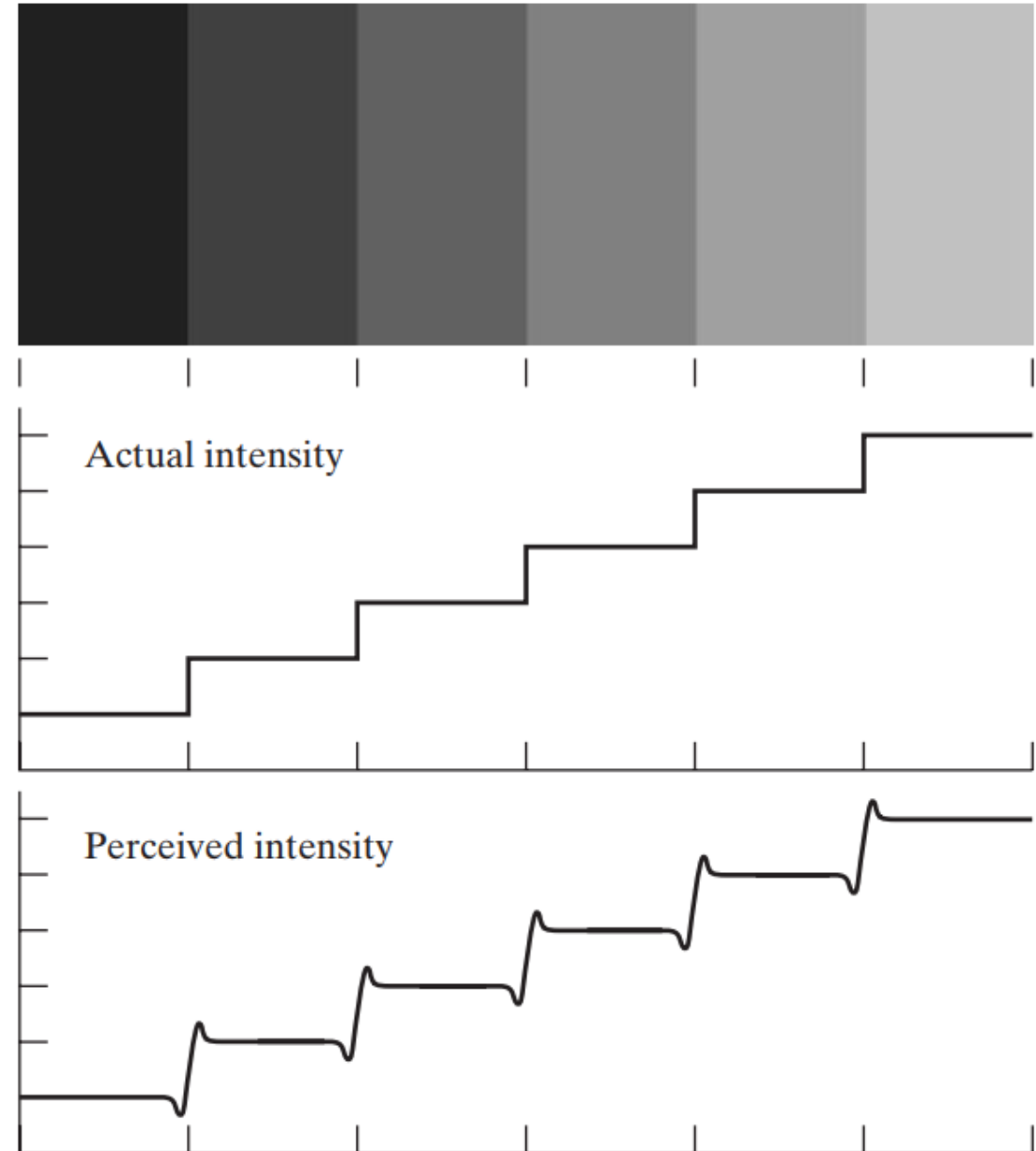
- Brightness adaption
  - system dynamics change
  - to achieve large dynamic range
  - by changing its overall sensitivity





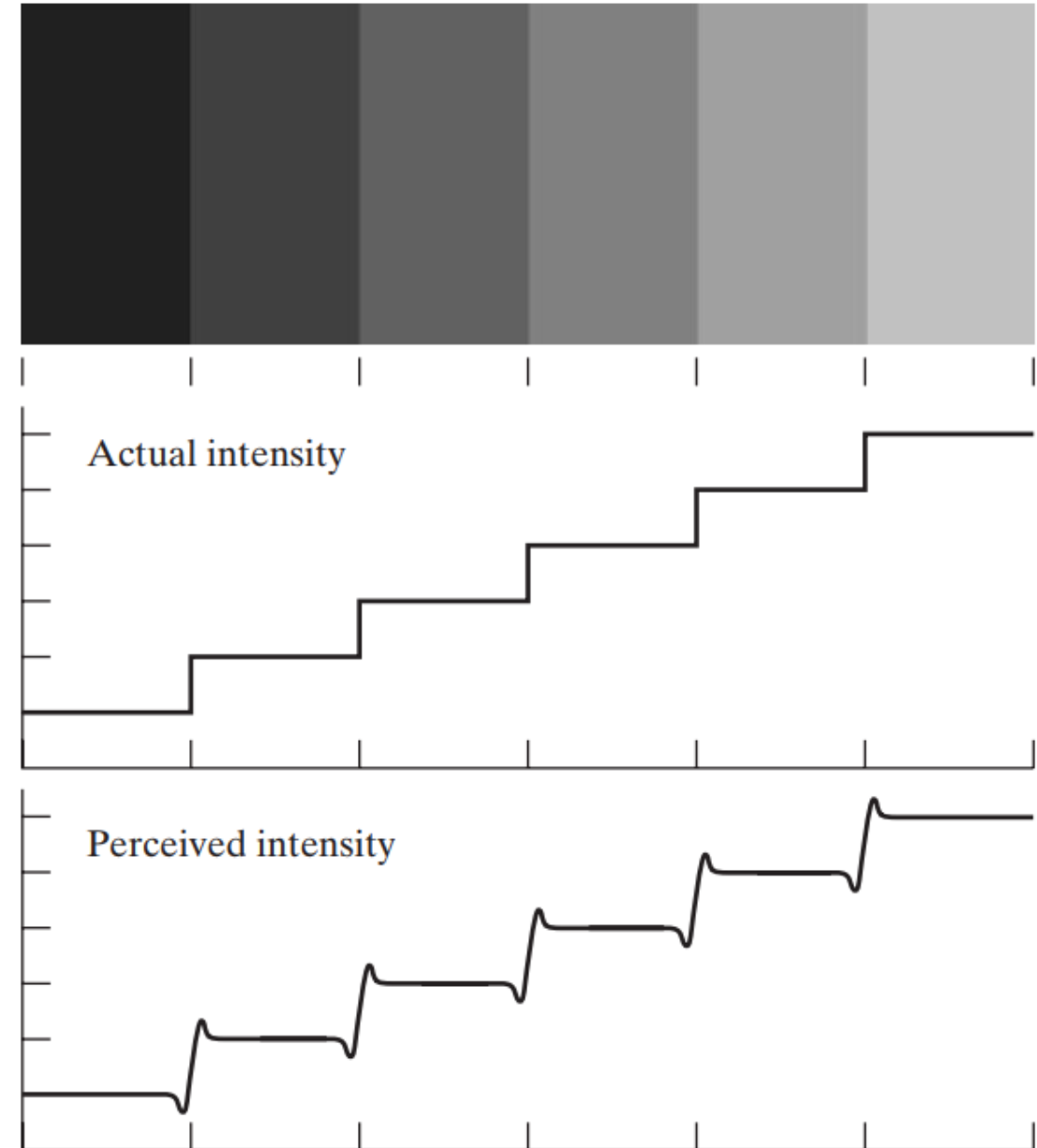
# Mach band effect

- Human perception
  - Characteristics of HVS



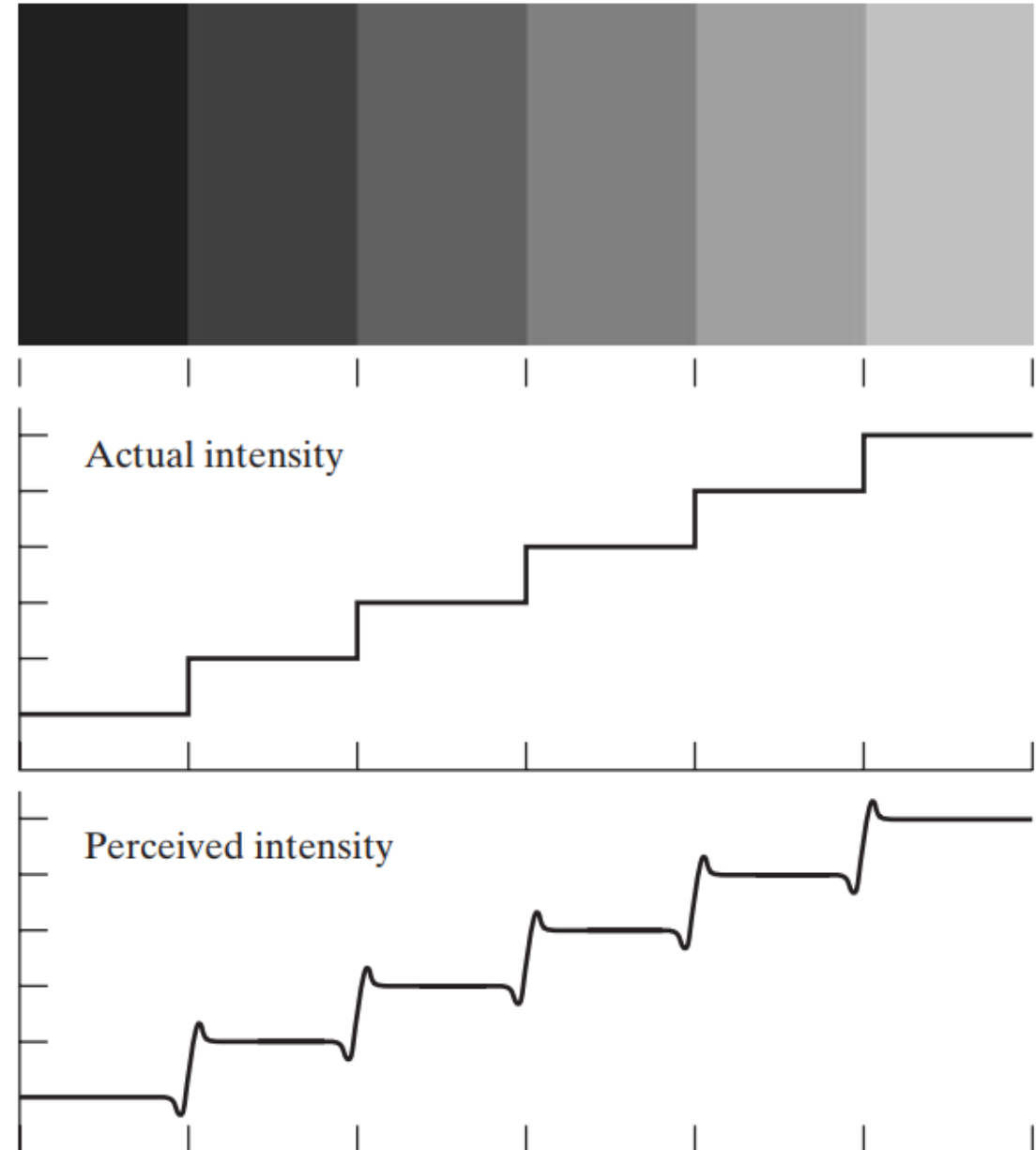
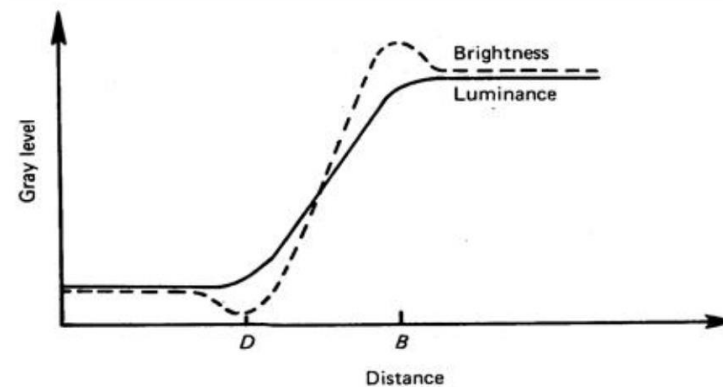
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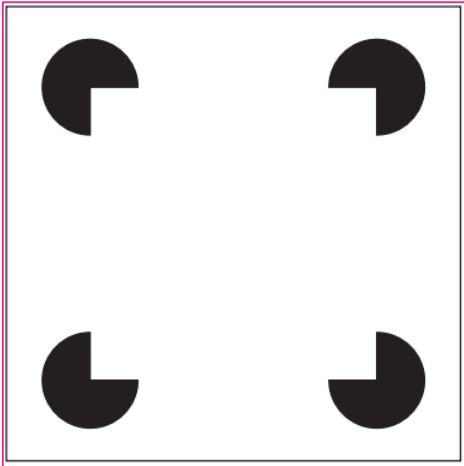
- Human perception
  - Characteristics of HVS



# Optical illusions

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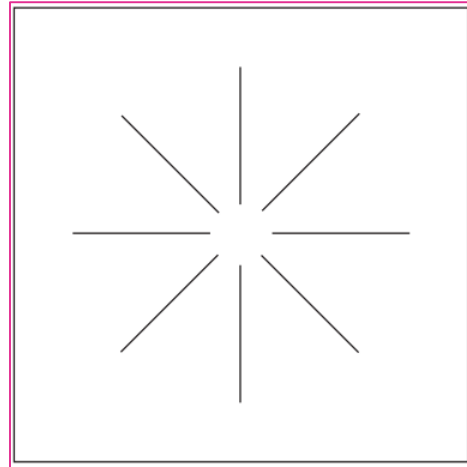
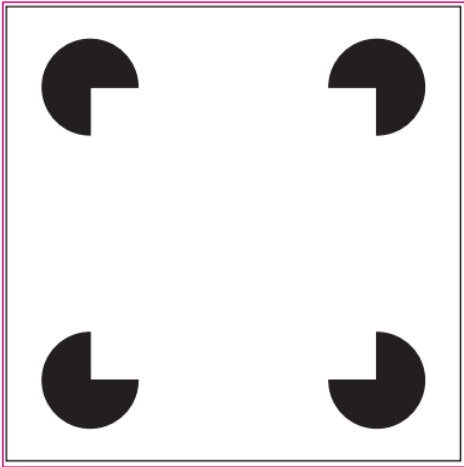
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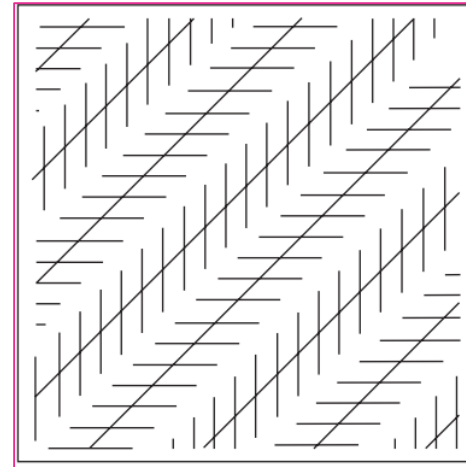
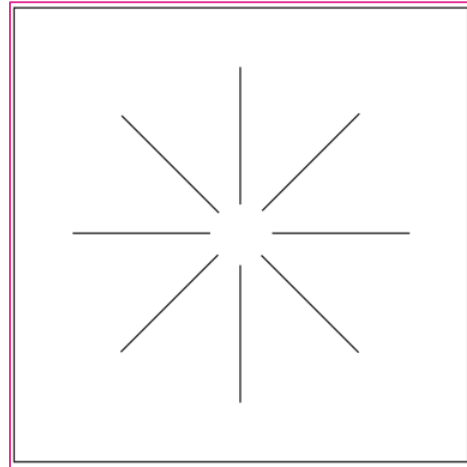
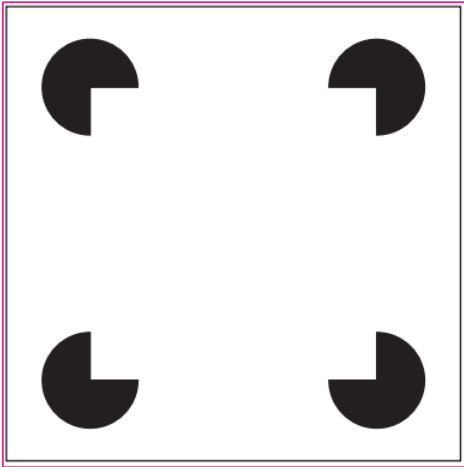
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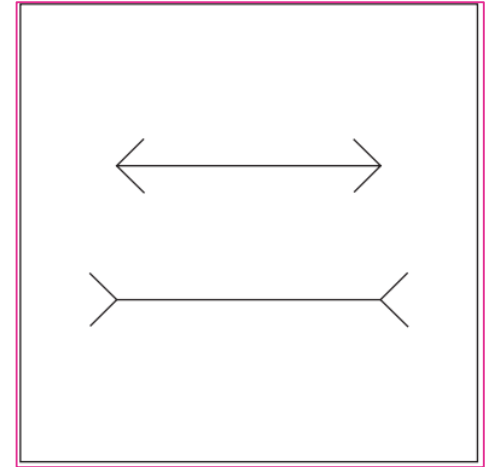
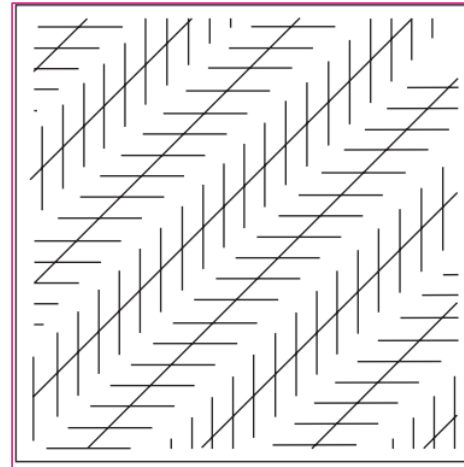
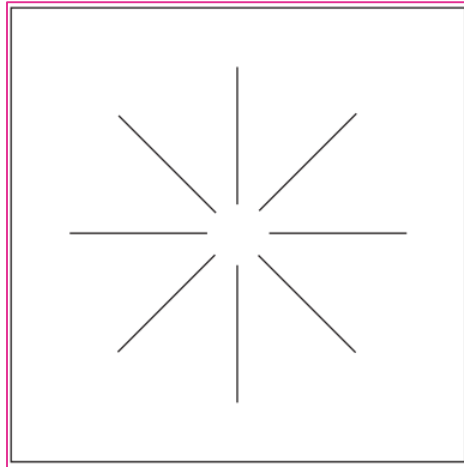
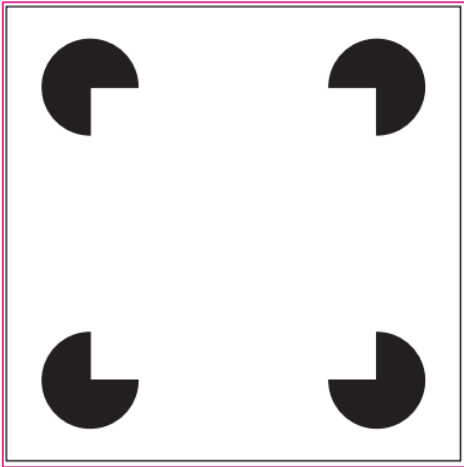




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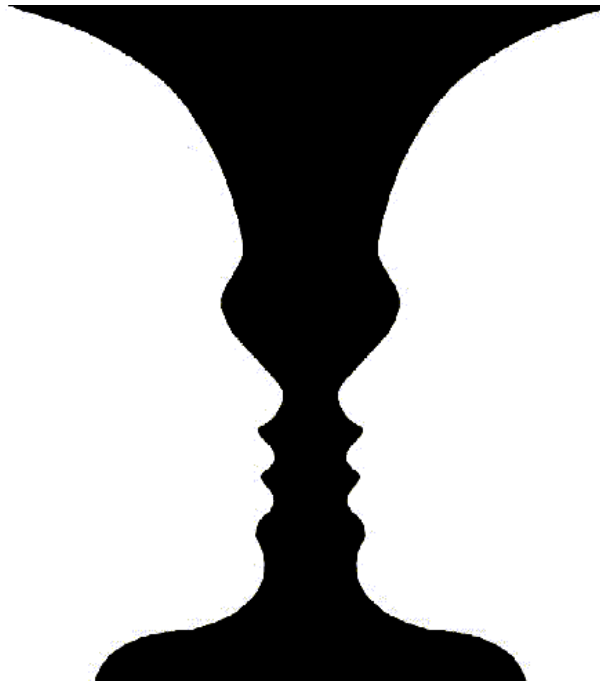
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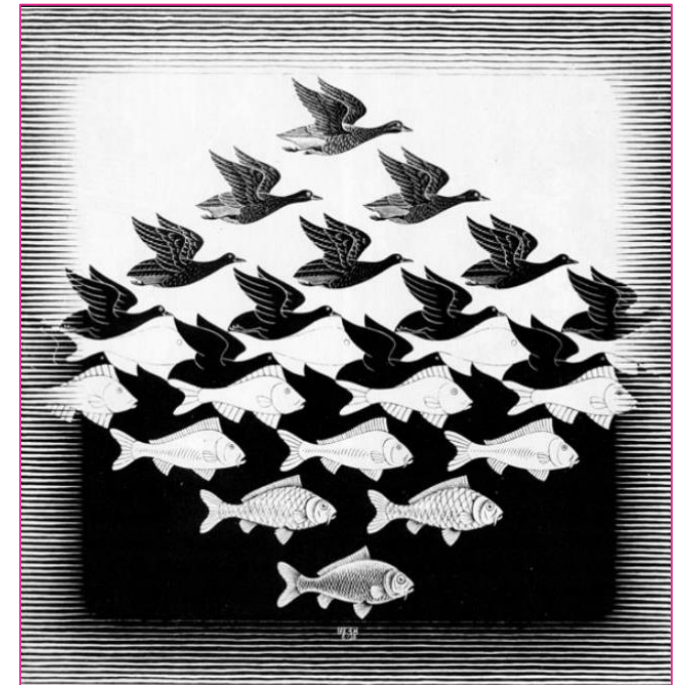
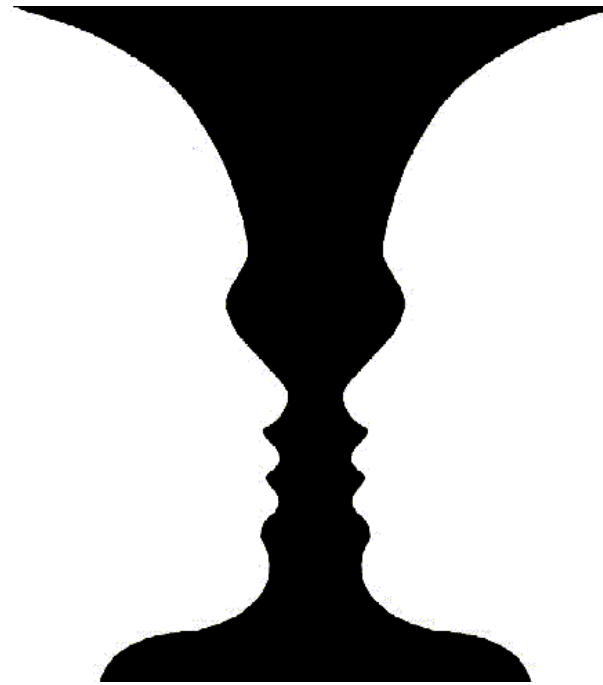
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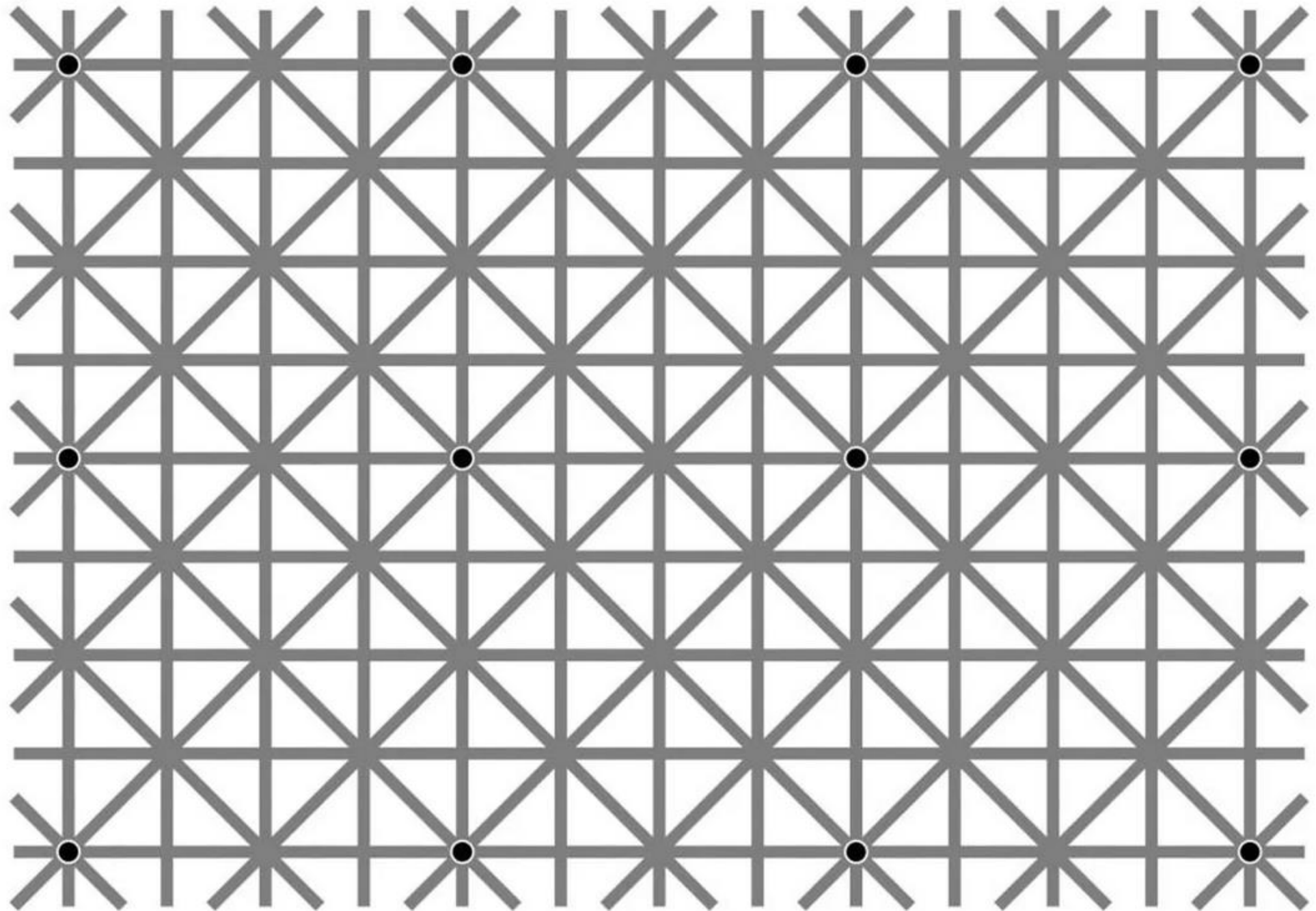
- Human perception
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# Illusion

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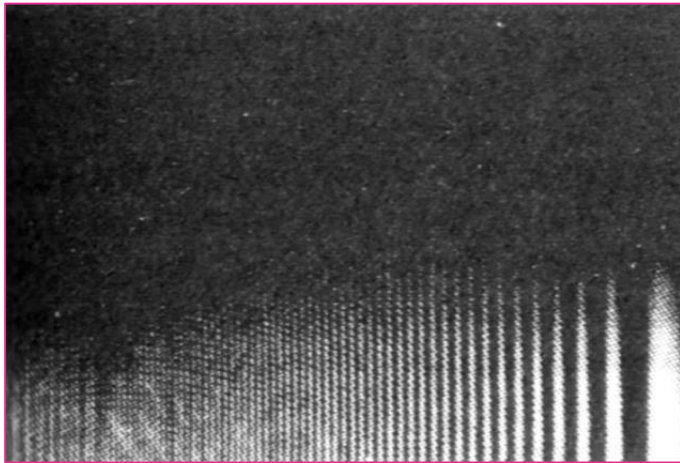
- How many black dots?



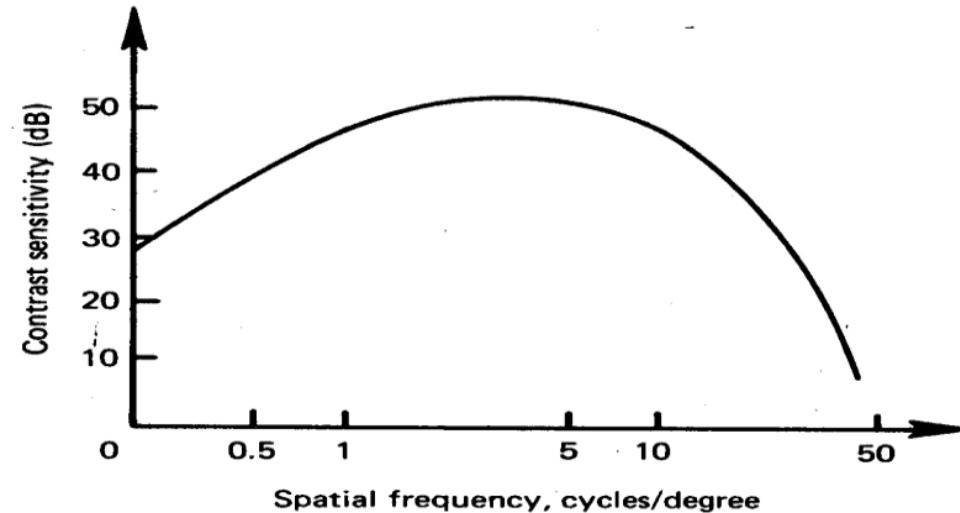
# Spatial frequency response

- Human perception
  - characteristics of HVS
  - daily life application?

Contrast  
variation



Frequency variation





# Vision system

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- HVS vs other vision systems
    - HVS: 3 modality of cones (red, green, blue)
    - Sensing
    - Interpretation
- } Perception

# Vision system

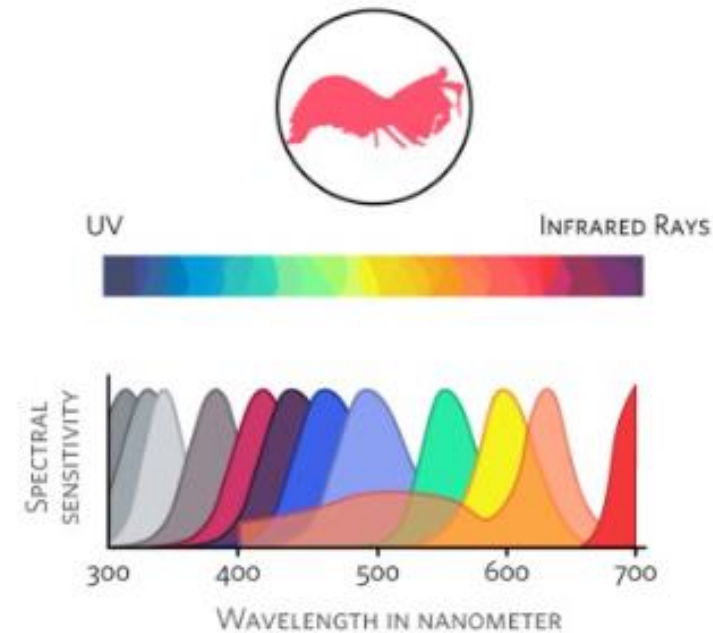
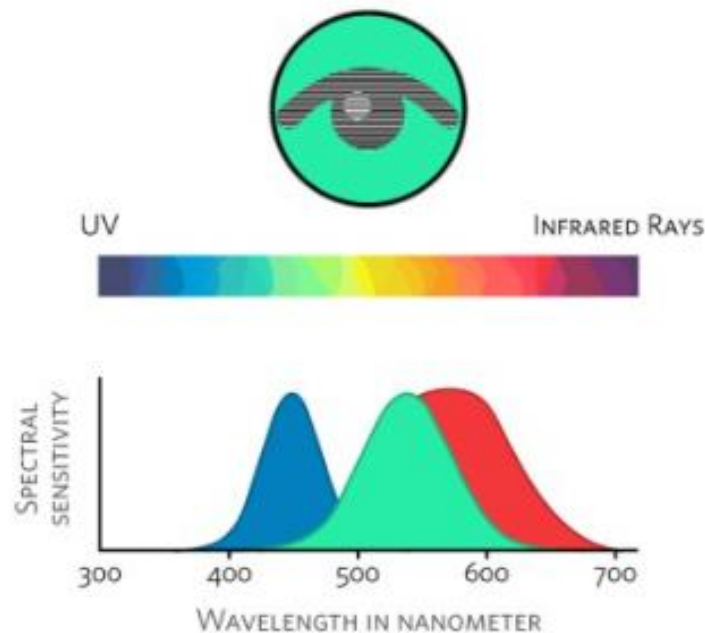
- HVS vs other vision systems

- HVS: 3 modality of cones (red, green, blue)

- Sensing

- Interpretation

} Perception



# Conclusion

- General visual systems
- Human visual system

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- General visual systems
- Human visual system

- ❑ Visual system comprised of
  - Sensors (specialized cells: rods, cones)
  - Light controllers (lens, supporting muscles and fluids)
  - Interpreters (brain)
- ❑ Visual system
  - Perception
- ❑ Compound lens
- ❑ HVS components